Ultra-high Specific Impulse Lithium-fueled Ion Thruster for Interstellar Precursor Mission Concepts

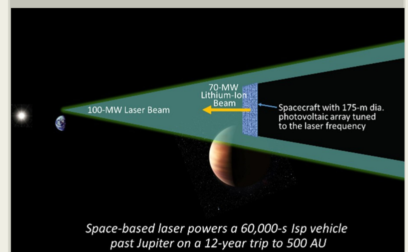
Completed Technology Project (2016 - 2018)

Project Introduction

Design, fabricate, and test a lithium-fueled, gridded ion thruster with a specific impulse of 60,000 seconds. This specific impulse represents an 10x improvement over the state of the art and has the potential to enable deep space missions with velocities that are ten times greater than currently possible. Such missions could include a mission to 500 astronomical units (AU) from Earth with a trip time of roughly 12 years, 3.6-year rendezous missions to Pluto, or 6-month flight times to Jupiter rendezvous. The thruster is being designed to operate at up to 100 kW at 60,000 s and will be tested in JPL's unique condensible-metals vacuum test facility.

The development of a lithium-fueled, gridded ion thruster that provides a specific impulse of 58,000 s takes advantage of the unique properties of lithium. Lithium's light atomic mass enables a very high specific impulse at a reasonable accelerating voltage, ~12 kV. In contrast, to obtain a specific impulse of 58,000 s with xenon would require a net accelerating voltage of 230 kV which would require an enormous mass of power conversion hardware and thermal radiator mass. The lithium-based system eliminates these masses along with their associated inefficiencies and waste heat. In addition, lithium can be stored as a solid at room temperature. This is critical to minimize the tank mass required to contain the propellant. Importantly, while lithium can be stored as a solid, it is easily melted, vaporized, and ionized. Lithium's ionization properties are critical to our overall system architecture. Lithium has a first ionization potential of 5.4 eV, less than half that of xenon, making it easy to ionize. However, it has a double ionization potential of 76 eV making it virtually impossible to doubly ionize in our application. This is expected to enable the thruster to be operated with nearly 100% ionization of the propellant effectively eliminating the loss of un-ionized lithium atoms from the thruster and the corresponding production of charge-exchange ions outside of the thruster. This has two important implications in our application. First, charge-exchange ions are responsible for the primary wear-out failure mode for gridded ion thrusters. The virtual elimination of these ions should enable the development of lithium-fueled ion thrusters that have extremely long lifetimes, much longer than state-of-the art ion thrusters. Second, the charge-exchange plasma adversely interacts with high-voltage solar arrays in solar electric propulsion systems. The effective elimination of the charge-exchange plasma in our lithium-ion thrusters will greatly mitigate this interaction. The 100-kW Li-fueled thruster will have a diameter of just 250 mm, produce a beam current of 8 A at 12,000 V. The discharge current is expected to be approximately 80 A. Successful development and operation of this thruster is expected to pave the way for the development of a much higher power version with power levels in the multi-megawatt range needed for rapid transportation throughout the solar system.

Anticipated Benefits

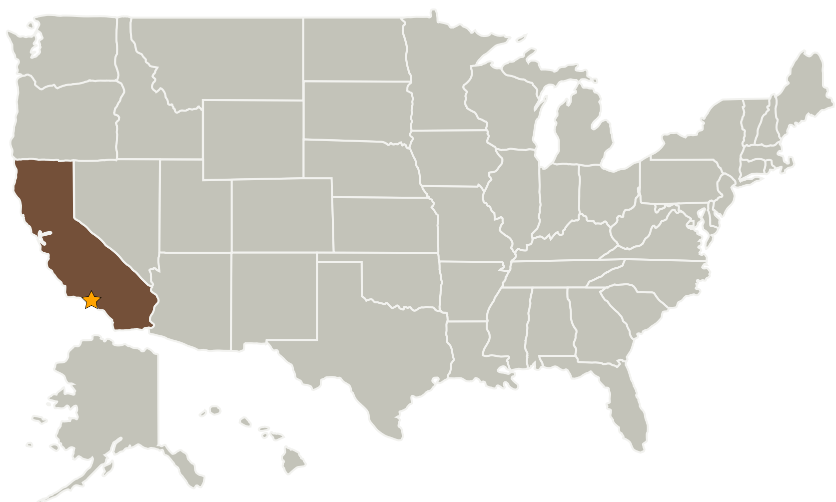


Concept for a Space-based laser that powers a 60,000-s Isp vehicle past Jupiter on a 12-year trip to 500 AU.

Table of Contents

The ultra-high specific impulse lithium-fueled ion thruster is a key component of a new power and propulsion architecture to enable delivery of a conventionally sized spacecraft (i.e., New Horizons-sized of order 300 kg) to ~500 AU from Earth—the distance at which solar gravity lensing can be used to image exoplanets [1]—with a flight time of just 12-years. For comparison, the fastest spacecraft ever flown, Voyager 1, has been traveling for 39 years at ~4 AU/year and is at 135 AU today. Our architecture would result in a spacecraft speed an order of magnitude greater or ~40 AU/year. This architecture would also enable orbiter missions to Pluto in just 3.6 years or to Jupiter in 170 days. Alternatively, it could deliver an 80-metric-ton payload to Jupiter orbit in just one year, opening the possibility of human missions to the Jovian system.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations
California

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

Center Independent Research & Development: JPL IRAD

Project Management

Program Manager:

Fred Y Hadaegh

Project Manager:

Fred Y Hadaegh

Principal Investigator:

John R Brophy

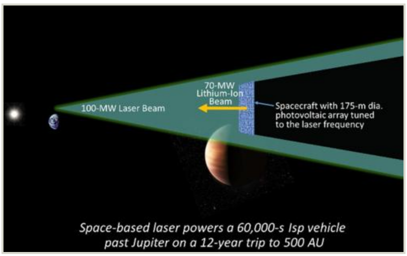
Co-Investigators:

Leon Alkalai
Nitin Arora
James E Polk

Ultra-high Specific Impulse Lithium-fueled Ion Thruster for Interstellar Precursor Mission Concepts

Completed Technology Project (2016 - 2018)

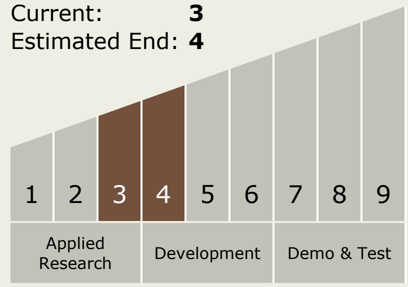
Images



JPL_IRAD_Activities Project Image
Concept for a Space-based laser that powers a 60,000-s Isp vehicle past Jupiter on a 12-year trip to 500 AU.
(https://techport.nasa.gov/image/27835)

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX01 Propulsion Systems
  └ TX01.1 Chemical Space Propulsion
    └ TX01.1.8 Warm Gas

Target Destinations

Others Inside the Solar System, Outside the Solar System, Foundational Knowledge

Supported Mission Type

Push